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Method of Magnetic Resonance Imaging

Field of the invention

The invention relates to magnetic resonance imaging (MRI) of invasive devices, e.g. during surgical and therapeutic procedures, and to devices for use with the procedures.

Description of related art

Interventional procedures in radiology are very common and increasingly popular. They are normally performed under fluoroscopic feedback by insertion of various devices through the blood vessels. The procedures can last for several hours and involve very high radiation doses for the patient and for the personnel performing the procedure. During the procedures it is frequently desirable for the physician to be able to locate or guide invasive devices inserted into the body (for example catheters, guide wires, biopsy needles, etc.) when these are not directly visible to the naked eye. Since soft body parts give very little contrast on X-ray, it is often necessary to use high doses of iodinated contrast agents which may be problematic, in particular for patients with reduced kidney function.

MRI-guided interventional procedures have gained increasing importance in recent years. Such MRI guided procedures can be divided into two categories: intraoperative procedures, which integrate surgery with MRI, and interventional procedures for guiding, monitoring and controlling therapy. Intraoperative procedures generally require an open magnet MR imager and are desirable as the MRI can be used to define anatomy and monitor tissue function as it changes during surgery. Interventional procedures generally require only limited patient access and thus conventional, closed magnet MR imagers may be used.

The success of a MRI-guided interventional or intraoperative procedure generally depends on the ability of the MRI technique to provide accurate real time visualisation of the instruments and devices inserted into the patient's body. If the device is metallic and/or conductive it will act as a shield to the RF (radio frequency) irradiation and prevent it from reaching the contrast medium within the device, thereby causing imaging defects in the region surrounding it. On the other hand,

devices made of polymeric materials will not be visible in the MR image. A guide wire needs to be stiff enough to enable it to be pushed past contortions and turns and to rotate as a rigid body all the way to the tip when the operator pushes and twists the other end, which is often a meter away from the tip of the wire. Guide wires are usually made of a steel core wound with a Teflon coated steel wire. It has been suggested to use non-conductive devices marked by incorporating bands of paramagnetic material such as for example dysprosium oxide. Such marker bands produce artefacts in the image. It has further been proposed to fill the instruments or devices with a paramagnetic contrast agent (e.g. GdDTPA) or a "blood pool" contrast agent for example a ferromagnetic, ferrimagnetic or superparamagnetic contrast agent. The signal strength from such conventional MR contrast agents may however be inadequate for adequate "real time" tracking of the instrument. Furthermore, due to the toxicity of such agents, only limited amounts of agents may be administered or be released into a living body. Another problem with this technology or, in fact, any technology that relies on proton imaging, is the massive background signal from the water in the tissues, requiring either time consuming 3D acquisition or dynamic slice positioning.

US patent 5,211,166 proposes visualisation of a part of an operative instrument by providing the instrument with a NMR active nucleus in, or in proximity to, the instrument. The NMR active nucleus can be any nucleus suitable for NMR, such as the NMR active isotopes of hydrogen, phosphorus, carbon, fluorine and nitrogen. Additionally a paramagnetic relaxant is supplied and the signals of the NMR active nuclei are amplified by dynamic nuclear polarisation (DNP) to improve the visibility of the instrument. However it is difficult using in vivo polarisation enhancement as suggested in this document, at normal imager field strengths (>0.2 T), to achieve sufficient polarisation due to the limited penetration of the RF pulses through tissues and the instrument material, and thereby achieve a sufficient visualisation of the instrument. Another problem that occurs at higher fields is increased heating of the tissue surrounding the device. Furthermore, the amount of paramagnetic relaxant that can be released into living body tissue is also a constraint of this method due to potential toxicity of such materials.

WO 02/088766 proposes a method of monitoring the position of a medical instrument in vivo by introducing a hyperpolarised gas into a region within or adjacent to the instrument and imaging the hyperpolarised gas using NMR. The hyperpolarised gas can be dissolved in synthetic plasma, however only to a limited

extent. ^{129}Xe and ^{3}He gases are specifically mentioned. Because of their low spin density, the MR sensitivity of hyperpolarised gases is significantly lower than that which can be achieved with a nucleus incorporated in a soluble molecule in a suitable solvent when other factors such as polarisation and magnetogyric ratio are similar.

Summary of the invention

The objective of the present invention is to provide improved methods for facilitating passive visualisation of invasive devices as well as devices for use in the methods and utilisation of the methods in MR imaging, surgery and therapy. Related methods known from the prior art have drawbacks in that they expose the body under examination to high amounts of radiation, or that distortions and artefacts in the MR image are unavoidable, or the contrast agents employed fail to provide the desired contrast or they may have unacceptable toxicity at relevant doses.

It has surprisingly been found that passive visualisation of invasive devices can be facilitated by employing a hyperpolarised solution of a high T1 agent, i.e. having a T1 value of at least 5 seconds at a field strength in the range of 0.001-5 T and a temperature in the range of 20-40 degrees C during the time course of the visualisation procedure. Devices and instruments particularly useful for being employed in the methods are also provided as well as use of the methods in imaging, surgery and therapy.

Thus viewed from one aspect, the invention provides a method of interventional or intraoperative MRI wherein an invasive device is inserted into a human or non-human animal body and an MR image of at least a part of said body containing said device is generated, said method comprising introducing a contrast medium into and optionally through said device during the time course of the visualisation procedure in order to facilitate visualisation of said device in said image, the improvement comprising that the contrast agent comprises a hyperpolarised solid or solution of a high T1 agent having a T1 value of at least 5 seconds at a field strength of 0.001-5 T and at a temperature of 20-40 degrees C.

Viewed from a further aspect the invention provides the use of a contrast medium comprising a hyperpolarised solid or solution of a high T1 agent, i.e. having a T1 value of at least 5 seconds at a field strength of 0.001-5 T and a temperature of 20-40 degrees C for the manufacture of a MR contrast medium solid or solution

for use in a method of diagnosis, surgery or therapy wherein an invasive device is inserted into the tissue and/or vasculature of a human or non-human animal body and an MR image of at least part of said body containing said device is generated.

Viewed from a still further aspect the invention provides devices made of medium conductive material such as carbon fibre, e.g. carbon fibre composite material, for use in the method.

Further aspects of the invention will be evident from the claims and the specification.

The human or non-human animal body can be a mammalian, avian or reptilian body. "T1" means the longitudinal relaxation time normally measured in seconds, and "T" means Tesla.

Detailed description of the invention

Contrast media for use in the method comprising a hyperpolarised solid or solution of a high T1 agent, i.e. having a T1 value of at least 5 seconds at a field strength of 0.001-5 T and at a temperature of 20-40 degrees C are well known, e.g. from WO 9335508 which is hereby included by reference.

Suitable high T1 agents will contain nuclei with non-zero nuclear spin nuclei (polarisable nuclei) such as ^{19}F, ^{6}Li, ^{13}C, ^{15}N, ^{29}Si or ^{31}P in addition to ^{1}H, preferably ^{13}C, ^{15}N, ^{19}F, ^{29}Si and ^{31}P nuclei, with ^{13}C and ^{15}N nuclei being particularly preferred. Other nuclei may also be used such as ^{77}Se, ^{111}Cd, ^{113}Cd, ^{115}Sn, ^{117}Sn, ^{119}Sn, ^{123}Te, ^{125}Te, ^{171}Yb, ^{195}Pt, ^{199}Hg, ^{203}Tl, ^{205}Tl and ^{207}Pb, in particular for contrast media that will only be administered to the body in small amounts or will not get into contact with the living body tissue, for example, by being held in a closed circuit inside the device during the procedure.

Preferred contrast media are biocompatible compounds with low toxicity and high T1. The compounds may be used in solid form, e.g. as dispersions in a suitable solvent, but are preferably in solution, and preferably in a biotolerable solvent. Particularly preferred compounds are water-soluble molecules with a molecular weight below 200D (Dalton). The contrast media comprise chemical compounds where the polarisable nuclei are in its natural abundance or more preferable are enriched in a particular position of the compound. Preferred

compounds are enriched by ^{13}C and/or ^{15}N nuclei in one or more specific positions in the compound. Preferably the enriched compounds are also deuterium labelled. Preferred ^{13}C enriched compounds are those where the ^{13}C nucleus is surrounded by one or more non-MR active nuclei such as O, S, C or a double bond, for example a ^{13}C enriched compound at one or more carbonyl or quaternary carbons. Preferred compounds are compounds that occur naturally in the body such as amino acids, peptides, nucleic acids, carbohydrates and intermediates in the normal metabolic cycles and approved pharmaceuticals.

Chemical compounds for use in ablation procedures include carboxylic acids and alcohols such as ethanol enriched with ^{13}C. Alternatively, ablation procedures can be performed with normal carboxylic acid and alcohol such as ethanol with a minor amount of polarised compound, e.g. a ^{13}C labelled compound, added as a marker. For use in methods of therapy, suitable therapeutics preferably enriched with ^{13}C and/or ^{15}N can be used, for example F-uracil and receptor targeting drugs.

Contrast media for use in the method preferably comprise hyperpolarised solids or solutions of high T1 agents, enriched with the mentioned nuclei and having a T1 relaxation time of 10 seconds or more, preferably 30 seconds or more, especially preferably more than 60 seconds and even more preferably more than 100 seconds at a field strength of 0.001-5 T and at a temperature of 20 to 40 degrees C.

Methods for producing hyperpolarised solutions of high T1 agents are known, e.g. from WO99/35508 and WO 99/24080. Preferred methods comprise the Dynamic Nuclear Polarisation (DNP) method and the Parahydrogen (PHIP) method. By using these methods it is possible to obtain solutions of agents having a T1 of 5 seconds or more.

"Invasive devices" mean any invasive device and instrument used in interventional procedures such as catheters including balloon catheters, balloons, optical fibres, guide wires, needles e.g. biopsy needles, electrodes, electrode leads, implants and stents.

If it is desired to shield the contrast agents from RF (radio frequency) irradiation until the device filled with the contrast medium reaches the region of interest (ROI), it has been found that carbon fibre-containing material such as

carbon fibre composite material can be employed. Using e.g. a catheter containing carbon fibre material will prevent the contrast agent being depolarised by the RF irradiation employed during the placement of the catheter during the procedure. The contrast agent will remain "invisible" inside the device until it released at the ROI. Furthermore, carbon fibre material has low electrical conductivity compared to metals and will not cause substantial imaging artefacts during imaging nor tissue heating. Invasive devices made of carbon fibre materials are a further aspect of the invention.

The invention will be illustrated below by means of non-limiting examples of embodiments.

Description of the figures:

Figure 1 shows a first embodiment example of an invasive device in accordance with the present invention,

Figure 2 shows a carbon fibre tube as described in Example 2.

Figure 3 shows a second embodiment of an invasive device in accordance with the present invention.

Figures 4a)-4d) show schematically cross-sections through further embodiments of invasive devices in accordance with the present invention.

Figure 5 shows the stomach of a rat into which a guidewire has been inserted as described in Example 1.

Figure 1 shows a first embodiment of an interventional MRI invasive device (1) for use with hyperpolarised contrast media in accordance with the present invention. Invasive device (1) comprises a hollow, elongated body (3) of diameter D mm. Body (3) has a central lumen (5) and a wall (7) of thickness d mm. Invasive device (1) is intended to be inserted into the body of a patient and may be made rigid or flexible depending on the use to which it is to be put, e.g. rigid if it is to be used as a needle and flexible if it is to be used as a catheter. Body (3) is made of carbon fibre containing material such as carbon fibre composite material, which has surprisingly been found to be opaque to RF irradiation (as described below). This is surprising because carbon fibre composite materials are normally considered to be insulating, as their electrical conductivites are almost 600 times less than that of copper.

In this embodiment, invasive device (1) is suitable for transporting hyperpolarised contrast media from a first open end (9), which is intended to be outside the body of a patient and which is connectable to a supply of hyperpolarised contrast media (not shown), to a second open end (11) which is intended to be inserted into a patient and from which the hyperpolarised contrast media can released into the ROI of patient, for example into a blood vessel or body cavity. As invasive device (1) is opaque to RF irradiation, the hyperpolarised contrast media will not be depolarised by RF irradiation while it is shielded by the body (3).

When it is desired to visualise the devices during the entire procedure, the devices should be made of material transparent for RF (radio frequency) irradiation to provide sufficient signals from the contrast agent inside the device. Glass fibre reinforced polymer material is known to have the correct physical properties for devices such as guide wires, optical fibres, electrodes and electrode leads. Other construction polymers such as PEEK or PSU also have suitable characteristics. Needles and similar devices can be made of ceramic material such as dense zirconia, optionally coated with a polymer layer to make it less brittle or of glass fibre reinforced plastic material. Devices lacking a cavity for containing a contrast agent should be fitted with a cavity, preferably a cavity extending along the length of the device and preferably facilitating circulation of the contrast agent. Catheters may, for example, be made with double walls for circulation of the contrast agent. Refilling of contrast agent into the device through an external duct during the procedure will also be possible with such arrangements.

Figure 3 shows a second embodiment of an interventional MRI invasive device (31) for use with hyperpolarised contrast media in accordance with the present invention. Device (31) comprises a hollow, elongated body (33) of diameter D mm and has a wall (37) of thickness d mm. Body (33) comprises a first lumen (35') and a second lumen (35") which both extend from the open first end (39) of body (33) to the closed second end (41) of body (33). First lumen 35' and second lumen 35" are formed on either side of a central interior dividing wall (43) which extends from one side of the interior surface of body (33) to the, preferably diametrically, opposite side of the interior surface of body (33).

Interior dividing wall (43) does not extend all the way to the closed second end (41), thus first lumen (35') and second lumen (35") are in communication near

the second end (41) of device (31) through an opening (45) in dividing wall (43). This allows a fluid, e.g. introduced into first lumen (35') at open first end (39), to circulate along the length of first lumen (35), then pass through opening (45) in dividing wall (43) near to, or at, closed second end (41) and return via second lumen (35") to the open first end (39). For use in an interventional procedure, device (31) is made from a material transparent to RF irradiation and a contrast medium, preferably a hyperpolarised contrast medium, is circulated in the invasive device (31) by being introduced though first lumen (35') and extracted via second lumen (35"). In this way newly hyperpolarised contrast medium can be introduced into the device (31) as old contrast agent is extracted from it. The contrast medium allows the position of the device to be observed on a MR imager while it is being used on a patient.

In a further embodiment of the present invention, an invasive device comprising a hollow, elongated body is provided with a third lumen, which extends to the end of the device, which is intended to be introduced into a patient. This lumen can be used to accommodate a guide wire, which is used to position the device.

In another further embodiment of the present invention, an invasive device comprising a hollow, elongated body is provided with a third lumen, which extends to the end of the device, which is intended to be introduced into a patient. This lumen can be open at the end intended to be introduced into the patient and can be used to accommodate a tool. For example the lumen could be provided with an inflatable balloon which can be inflated once the device has been manoeuvred to a suitable position inside a patient. Alternatively the lumen could accommodate a biopsy needle, or a stent or the like. An example of such a device can be seen in cross-section in fig. 4a).

In another embodiment of the present invention, an invasive device is provided with more than three lumens, of which two may be made interconnecting to allow the circulation of a fluid, e.g. a contrast agent and the others may be used for introducing tools and/or fluids into a patient. See, for example, figure 4c).

The interventional or interoperative procedure could start with the uptake of a 2- or preferably a 3-dimensional proton image of the part of the body being

examined. The invasive device, e.g. a catheter is then introduced into the vasculature, e.g. the femoral artery, or into a tissue. When it is desired to visualise the device by the contrast agent during the procedure, the device is continuously filled with contrast agent through the external duct. The signal provided by the contrast agent will allow real time visualisation and stereotactic location of the device in the 3D proton image. The proton image of the area of interest can be updated during the procedure e.g. to compensate for movements. It is also possible to inject doses of contrast medium into the vasculare or tissue during the introduction of the device. For example, during the introduction of a catheter into an artery, it is possible to release doses of contrast medium from the device and in this way to examine the blood flow and the blood supply to an organ in real time. When the catheter has reached the final target contrast agent can be released for facilitating the interventional or interoperable procedure, for example percutaneous transluminal angiography (PTCA) with a balloon catheter optionally combined with the placement of a stent in the affected part of the artery.

The method described above is particularly favourable for surgical and therapeutic procedures conducted on subjects or anatomical structures of subjects which are particular sensitive to radiation. Examples of such subjects are pregnant women, small children and reproductive organs. In women, about 40% of all fertility problems result from blocked fallopian tubes. The method of the invention can therefore be utilised in procedures to examine the fallopian tubes and if necessary open such blockages interventionally by inserting a catheter through the vagina. This method forms a further aspect of the invention.

The described method is also useful for diagnosis and surgery on, and for precision biopsies of, solid tumours. In particular, tumours of the prostate and breasts could be sampled much more efficiently than with the currently used methods by simultaneous soft tissue visualisation and precision guidance of the biopsy needle.

The described method can also be used in ablation procedures to guide the placement of devices used clinically, e.g. interstitial laser induced thermotherapy (LITT), focussed ultrasound and RF-ablation. In these procedures it is of utmost importance to place the instrument used in exactly the correct position and to follow the ablation procedure, e.g. the destruction of solid tumours. By using a method in accordance with the present invention a catheter can be positioned exactly in the

right position and the vessels and surrounding tissue, as well as the tumour or structure to be removed, can be monitored during the ablation procedure.

A further aspect of the invention involves using chemicals in the ablation procedures; either alone or together with the methods described above. When the device, e.g. a catheter, is placed in the correct position either by using a RF transparent catheter with contrast agent or using a carbon fibre catheter, the catheter can be filled with a chemical substance effective in ablation procedures which contains, or is enriched with, hyperpolarisable nuclei such as carboxylic acid or alcohol. Alternatively, ablation can be performed with normal carboxylic acid or alcohol, e.g. ethanol, with a minor amount of polarised compound as a marker. The ablation procedure can then be monitored by MRI. ^{13}C or ^{15}N enriched compounds are preferred, e.g. ^{13}C enriched ethanol can be hyperpolarised and used for this purpose.

A still further aspect of the invention is related to utilising the method in therapy. As described above, a device such as a catheter can be exactly placed at the region in need of treatment and a hyperpolarisable compound, preferably one enriched with a polarisable nuclei such as ^{13}C and/or ^{15}N, can be instilled at the site. The effect of the treatment can then be followed with MRI. Examples of compounds comprises F-uracil, e.g. ^{13}C enriched and receptor targeting drugs (e.g. peptides) or bactericidal, fungicides etc. The contrast medium will hence have a dual function as contrast medium and therapeutically active medium. Alternatively the therapeutically active compound can be a normal compound with a minor amount of polarised compound added thereto.

Imaging parameters such as pulse sequences should be chosen carefully to achieve optimal results of the methods described above. Many methods for fast proton imaging are standard on modern MRI scanners and it is obvious to one skilled in the art how to re-write the software to be suitable for other nuclei. Especially suitable methods are spiral and radial scan k-space sampling, optionally with sliding window update of the image. An additional option is the use of interleaved stereoscopic projections to allow for real-time stereoscopic visualisation by means of red-green stereo glasses or any of the many known stereo visualisation techniques.

<u>Experimental:</u>

The following non-limiting examples illustrate features of the invention.

Example 1.

An aqueous solution of hyperpolarised dimethylsuccinate (1-^{13}C) was circulated in a closed loop moulded in a guidewire of glass-fibre reinforced plastic. The T1 of this compound under these circumstances is 70 s. The guidewire was inserted in the stomach of a rat and was imaged at the ^{13}C frequency at 4 images per second. The images were colour coded and overlaid with a proton image of the rat. The guidewire is clearly visible in the rat as can be seen from the images in Figure 5.

Example 2.

Figure 2 shows the results of an experiment carried out on an invasive device (1) with a body (3) made of carbon fibre with a diameter D of 10 mm and a wall thickness d of 1 mm. The electrical conductivity of the carbon fibre was $\approx 1 \cdot 10^5$ S/m (c.f. copper: $5.9 \cdot 10^7$ S/m). Device (1) was placed in a syringe containing water and imaged inside a 2.4 T magnet. Gradient echo images were acquired with echo time 1.8 ms as shown in figure 2a) and 5 ms as shown in figure 2b). Similar results were obtained with both echo times. Minor susceptibility artefacts (13) can be seen near the second open end (11) of the invasive device. No signal is obtained from the lumen (3) of the tube (except near to the second open end (11) where radio frequency radiation has entered the lumen (3) from said second open end (11)) showing that the wall (7) of the invasive device is opaque to radio frequency radiation.

Example 3

Examples of possible embodiments of invasive device cross-sections are shown in figures 4a) – 4d).

Figure 4a) shows an invasive device formed of two concentric tubes (401, 403), with the inner tube (403) held in place in the centre of the outer tube (401) by an open system of webs (405). A first lumen (407) is formed in the interior of said inner tube and a second lumen (409) is formed by the annular space between the two tubes (401, 403).

Figure 4b) shows an invasive device formed of two concentric tubes (411, 413), with the inner tube (413) held in place in the centre of the outer tube (411) by two continuous webs (415', 415"). A first lumen (417) is formed in the interior of said inner tube (413) and a second lumen (419') and a third lumen (419") are formed by the semi-annular space between the two tubes (411, 413) and the webs (415', 415").

Figure 4c) shows an invasive device comprises an elongated body (421) with four lumens (423) formed in it.

Figure 4d shows an invasive device comprising an elongated body (431) with a central lumen (433) and two crescent shaped lumens (435', 435") attached to the outer wall of said body (431).

Preferably the dimension D is less than 20 mm, most preferably below 10 mm and greater than 1 mm, and dimension d is preferably less than D/5 and most preferably less than D/10

Further embodiments_and modifications to invasive devices are also possible under the scope of the following claims.

Claims

1. Use of a hyperpolarised solid or solution of a high T1 agent having a T1 value of at least 5 seconds at a field strength of 0.001-5 T and a temperature of 20-40 degrees C for the manufacture of a MR contrast medium for use in a method of diagnosis, surgery or therapy wherein an invasive device is inserted into a human or non human animal body and an MR image of at least part of said body containing said device is generated to visualise said device.

2. Use as claimed in claim 1 where said high T1 agent comprises the nuclei ^{19}F, ^{6}Li, ^{13}C, ^{15}N, ^{29}Si or ^{31}P, preferably ^{13}C, ^{15}N, ^{19}F, ^{29}Si and ^{31}P nuclei and most preferably ^{13}C and ^{15}N nuclei.

3. Use as claimed in claim 1 where said high T1 agent comprises the nuclei ^{77}Se, ^{111}Cd, ^{113}Cd, ^{115}Sn, ^{117}Sn, ^{119}Sn, ^{123}Te, ^{125}Te, ^{171}Yb, ^{195}Pt, ^{199}Hg, ^{203}Tl, ^{205}Tl and ^{207}Pb.

4. Use as claimed in claims 1 to 3 where said high T1 agent have a T1 value of at least 10 seconds or more, preferably 30 seconds or more, more preferably 60 seconds or more and still more preferably of more than 100 seconds at a field strength of 0.001-5 T and a temperature of 20-40 degrees C.

5. Use as claimed in any of claims 1 to 4 where the device contains a cavity for holding the contrast medium, the cavity preferably fitted with a outside duct for facilitating circulation and addition of contrast medium.

6. Use as claimed in claim 5 where said invasive device is made of a medium conductive material containing carbon fibre.

7. Use as claimed in any of the preceding claims where the invasive device is inserted into a tissue and/or vasculature of a body.

8. Use as claimed in any of the preceding claims where the contrast medium additionally is therapeutically active medium.

9. Use as claimed in claim 8 where the therapeutic active medium is instilled at

the region of interest via the device.

10. Use as claimed in any of the preceding claims for diagnosis and optionally surgery on the fallopian tubes.

11. Use as claimed in any of the preceding claims for diagnosis and optional surgery on tumours.

12. Use as claimed in any of the preceding claims for diagnosis by biopsy, e.g. breast and prostate biopsy.

13. Use as claimed in any of claims 1 to 6 in ablation procedures where an additional hyperpolarised compound effective in ablation procedures is introduced through the device.

14. A method of interventional or intraoperative MRI wherein an invasive device is inserted into a human or non human animal body and an MR image of at least a part of said body containing said device is generated, comprising introducing a contrast medium into and optionally through said device during the time course of the visualisation procedure whereby to facilitate visualisation of said device in said image, characterised in that the contrast agent comprises a hyperpolarised solid or solution of a high T1 agent having a T1 value of at least 5 seconds at a field strength of 0.001-5 T and at a temperature of 20-40 degrees C.

15. Invasive device, for use with the contrast medium and in the method of the preceding claims comprising a hollow elongated body made of carbon fibre containing material characterised in that said body is opaque to radio frequency radiation.

16. Invasive device according to claim 16 characterised in that the hollow elongated body is made of carbon-fibre composite material

17. Invasive device, for use with the contrast medium and in the method of claims 1 to 14 comprising a hollow elongated body with a first end and a second end, a first lumen extending from said first end to said second end and a second lumen extending from said first end to said second end, characterised in that said body is

transparent to radio frequency radiation and that said first lumen is in communication with said second lumen near to said second end.

18. Invasive device in accordance with claims 16 and 17 characterised in that it comprises more than 2 lumens.

Abstract:

The present invention provides methods for passive visualisation of invasive devices by employing a hyperpolarised solution of a high T1 agent. The agent should have a T1 value of at least 5 seconds at a field strength in the range of 0.001-5 T and a temperature in the range of 20-40 degrees C during the time course of the visualisation procedure. Devices and instruments particularly useful for being employed in the methods are also provided as well as use of the methods in imaging, surgery and therapy.

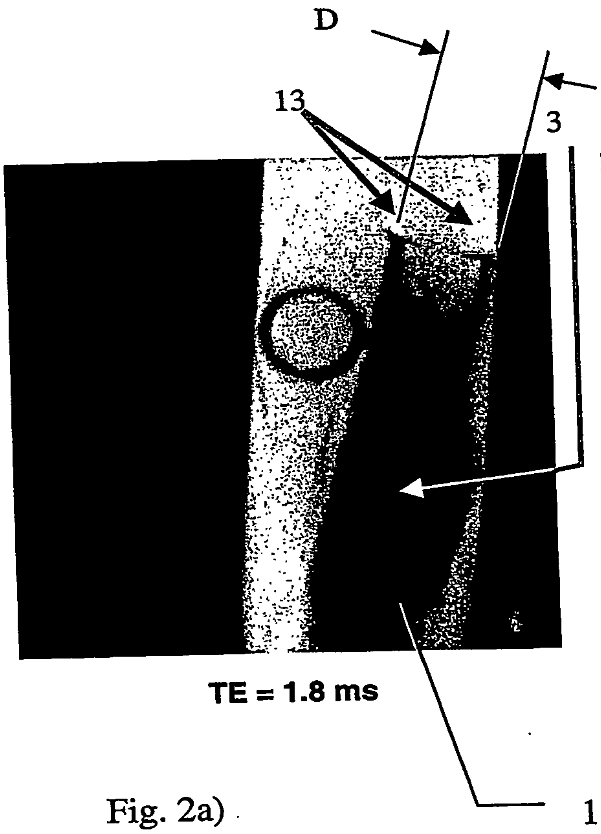

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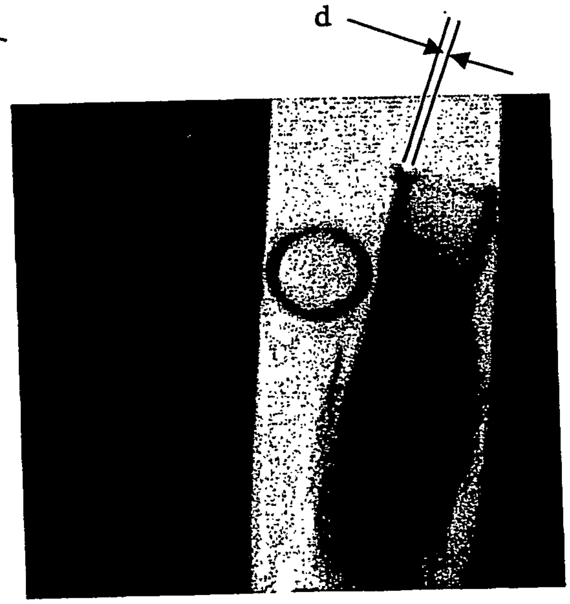
Fig. 2a)



TE = 5 ms

Fig. 2b)

Figure 5